Analysis of DITL root data and comparison with a full-resolver's data

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Updates from my previous analysis

- Analyzed DITL data from 2006 to 2010
  - Added some new graphs

- Compared with full-resolver data in 2012
  - A full-resolver sent 100,000 queries to root within 48 hours
  - It may be a typical full-resolver

- Previous analysis was reported at DNS-OARC 2013 Fall Workshop

Datasets and analysis method

DNS-OARC Root Datasets (1)

- "A Day in the Life of the Internet" (DITL) is a large-scale data collection project undertaken by CAIDA and DNS-OARC every year since 2006.
  - https://www.dns-oarc.net/oarc/data/ditl
  - 50 hours packet capture at root DNS servers and other DNS servers (48 hours are used by this analysis)
  - Source IP addresses of i.root-servers.net data are anonymized

DNS-OARC Root Datasets (2)

Year	Start (UTC)	End	List of root servers
2006	Jan 10 0000	Jan 12 0100	c,e,f,k (4/13)
2007	Jan 09 0000	Jan 11 0000	c,f,k,m (4/13)
2008	Mar 18 0000	Mar 20 0000	a,c,e,f,h,k,l,m (8/13)
2009	Mar 30 0000	Apr 02 0000	a,c,e,f,h,k,l,m (8/13), 72 hours
2010	Apr 14 0000	Apr 16 0000	a,b,c,d,e,f,g,h,i,j,k,l,m (12/13)
2011	Apr 12 1200	Apr 14 1200	a,c,d,e,f,h,j,k,l,m (10/13)
2012	Apr 17 1200	Apr 19 1200	a,c,e,f,h,j,k,l,m (9/13)
2013	May28 1200	May30 1200	a,c,d,e,f,h,j,k,l,m (10/13)

Analysis method of Root data

- Newly developed C program reads pcap files
- It counts number of some kinds of queries per IP address
  - All queries, RD=0 queries, EDNS0 queries,
  - DO set queries, name error queries,
  - "." DNSKEY queries (RD=0), “.” NS queries,
  - "." Queries, UDP checksum off queries
  - Port number bitmaps (to analyze source port randomization trends)
  - TLD bitmaps

University of Tsukuba Dataset

- Associate researchers and the author collected packet captures at one of full-resolvers at University of Tsukuba
- Around January 2011 to August 2012
- A data exist at the same timing as DITL-2012
  - Apr 17 12:00 to Apr 19 12:00 UTC
  - 72,355,778 DNS packets captured (418 pps)
  - 28,815,955 stub queries observed (166 qps)
  - 8429 unique query source addresses

Analysis method of full-resolver data

- Newly developed perl program
  - reads pcap files
  - classifies packets into
    - Stub queries/responses
    - Full-resolver to authoritative queries/responses
  - classifies destination addresses into
    - Root, TLDs, other authoritative servers
  - parses each section
  - parses referrals (NS+glue)
  - counts characteristics

Results

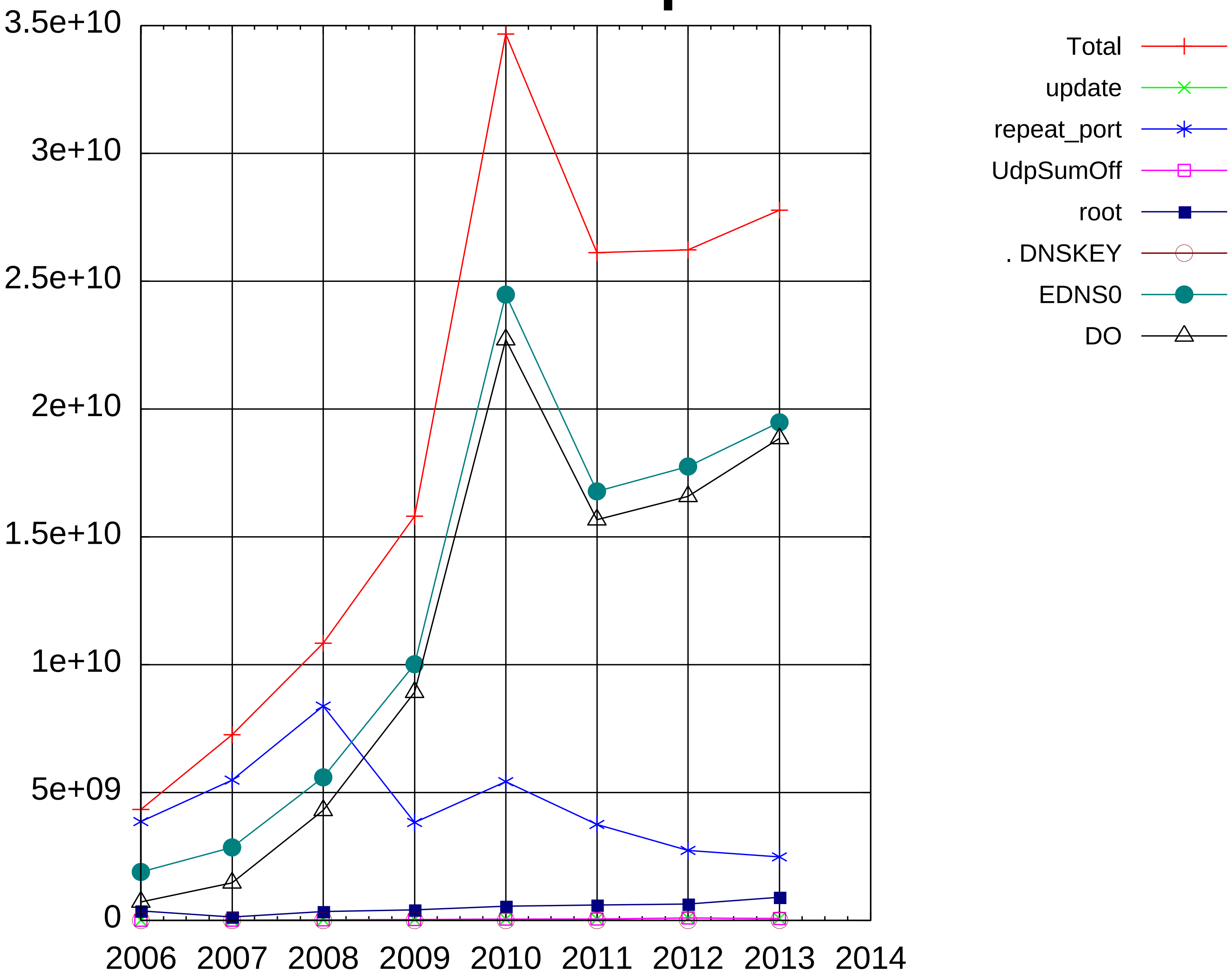
Number of IP addrs seen at root 48h

Year	2011		2012		2013	
Data from	10 root		9 root		10 root	
Total	7,591,031	100%	8,989,786	100%	8,547,065	100%
RD0	5,846,612	77.0%	5,859,493	65.2%	6,081,035	71.1%
EDNS0	2,340,543	30.8%	2,906,287	32.3%	3,572,804	41.8%
DO=1	2,018,839	26.6%	2,621,660	29.2%	3,283,728	38.4%
Update	105,131	1.4%	138,778	1.5%	228,633	2.7%
Update Only	71,972	0.9%	99,902	1.1%	179,874	2.1%
Non-existent TLD	2,606,340	34.3%	2,641,072	29.4%	2,619,836	30.7%
Existing TLD	7,361,794	97.0%	8,697,606	96.7%	8,142,126	95.3%
. NS	1,940,015	25.6%	1,871,995	20.8%	2,082,649	24.4%
. Only	26,877	0.4%	36,920	0.4%	105,784	1.2%
. DNSKEY (RD0)	14,092	0.2%	43,782	0.5%	269,390	3.2%
. DNSKEY . Only	571	0.0%	2,828	0.0%	64,612	0.8%

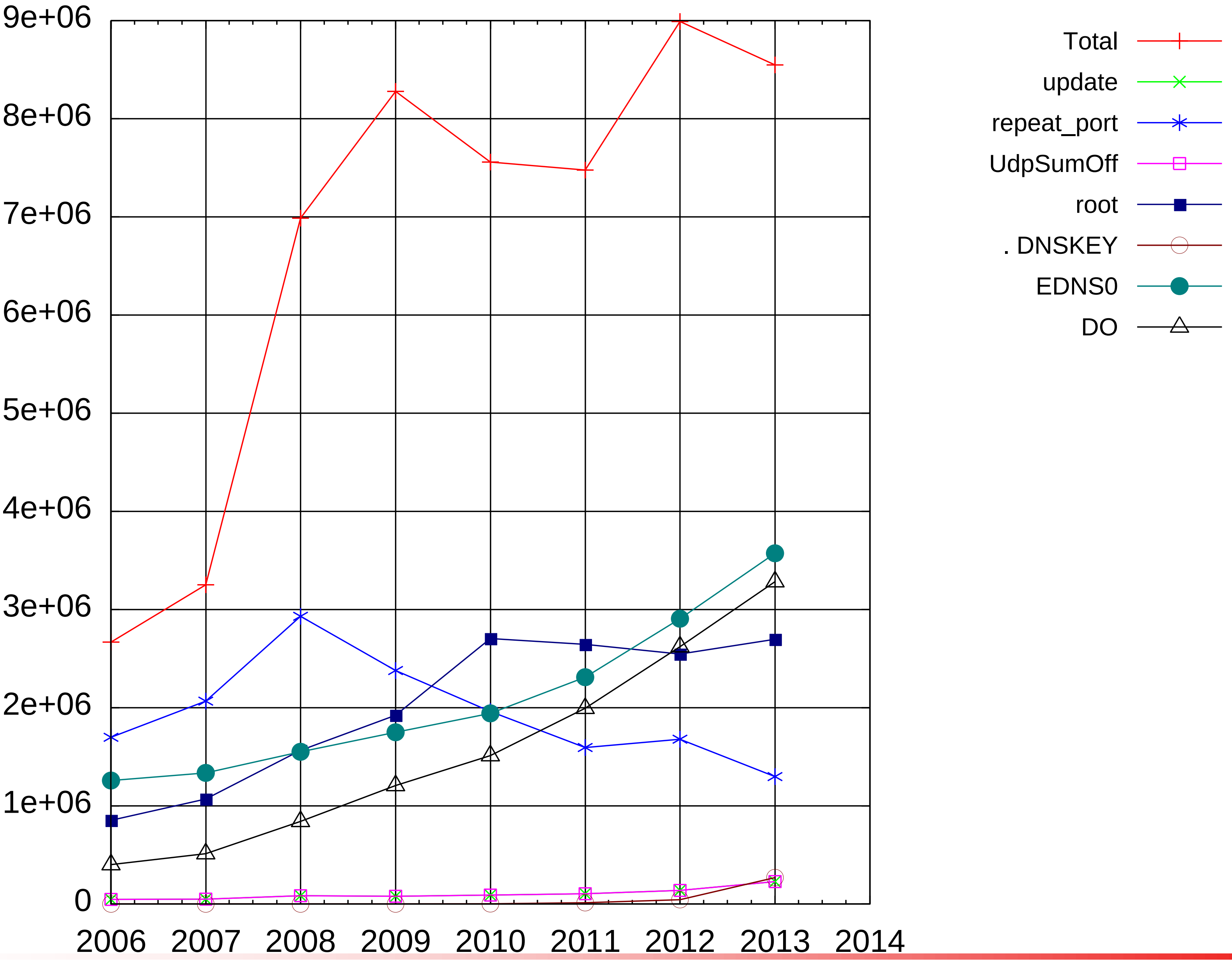
New graphs

- Horizontal axis: years from 2006 to 2013
- Graphs
  - Number of queries
  - Number of IP addresses
  - Ratio of IP addresses/queries
  - Port randomization status
- Data
  - Total, Update, EDNS0, DO
  - Repeat_port … an IP address sent from same port
    - one case of using static source port number
  - UdpSumOff
  - root: query name "."
  - "." DNSKEY

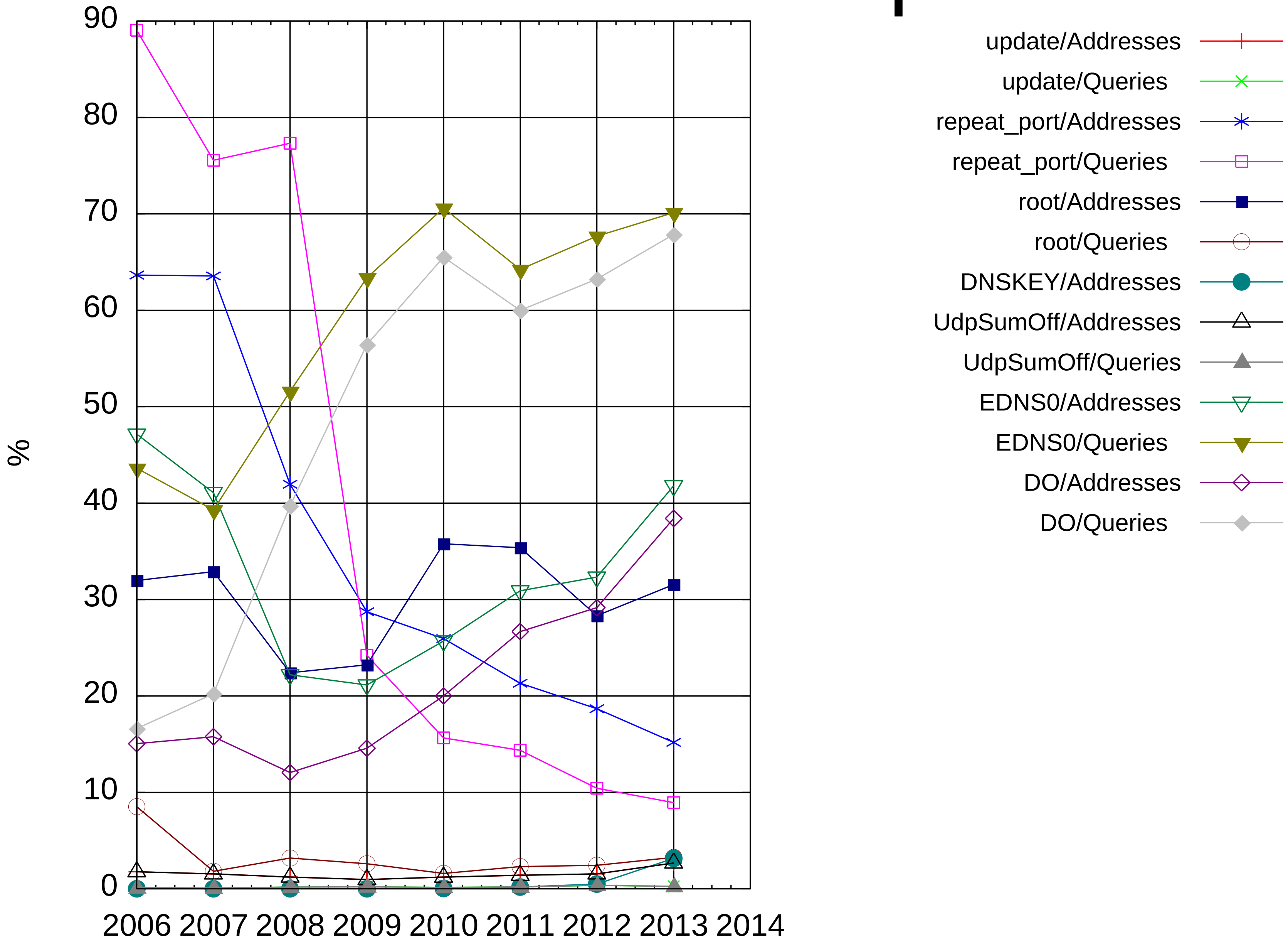
Number of queries



Number of IP addresses



Ratio of addresses/queries



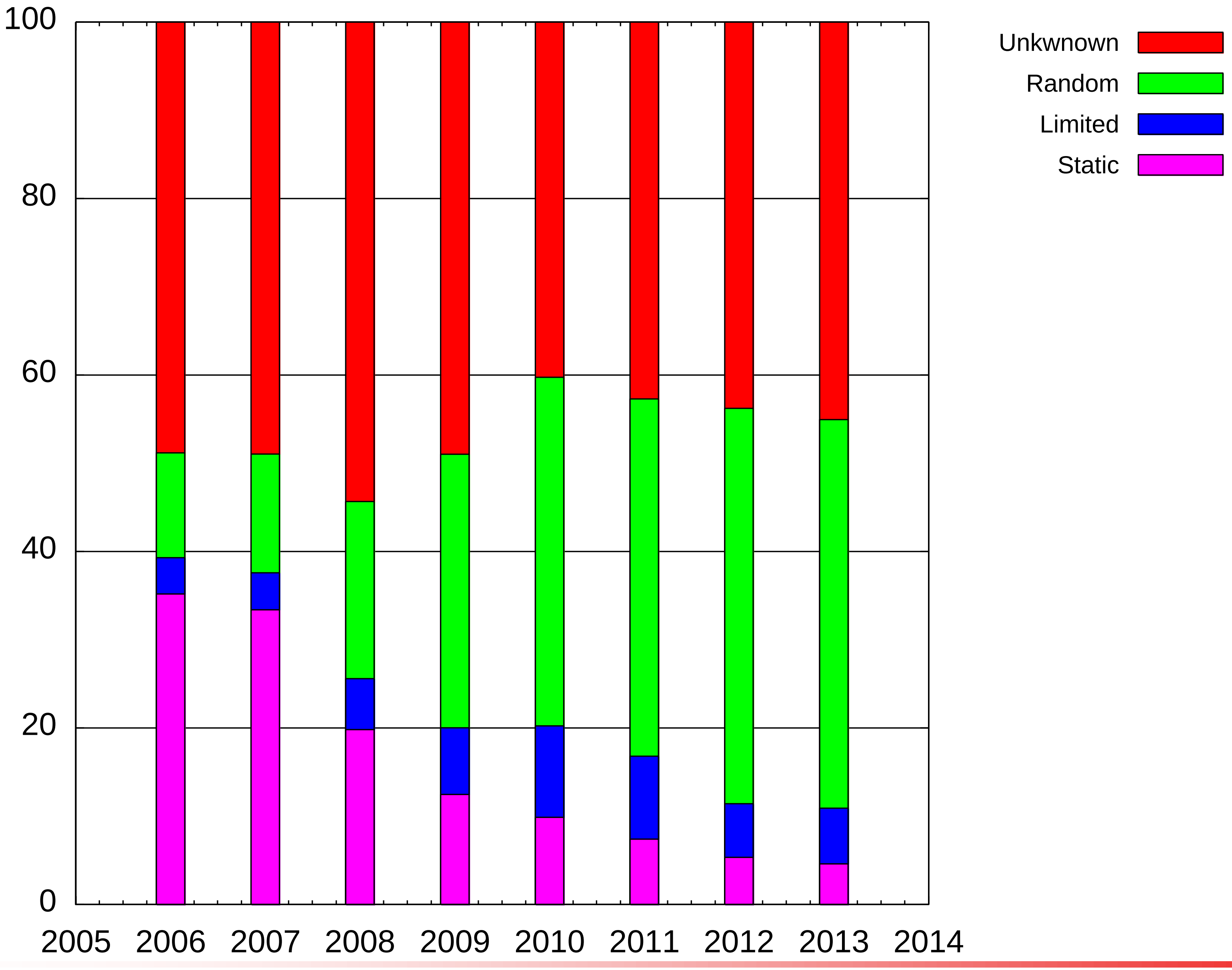
Status of port randomization

- High8 .. High 8 bits of port number
- Low8 .. Low 8 bits of port number
- OrderChange .. Number of changes of port numbers increase and decrease

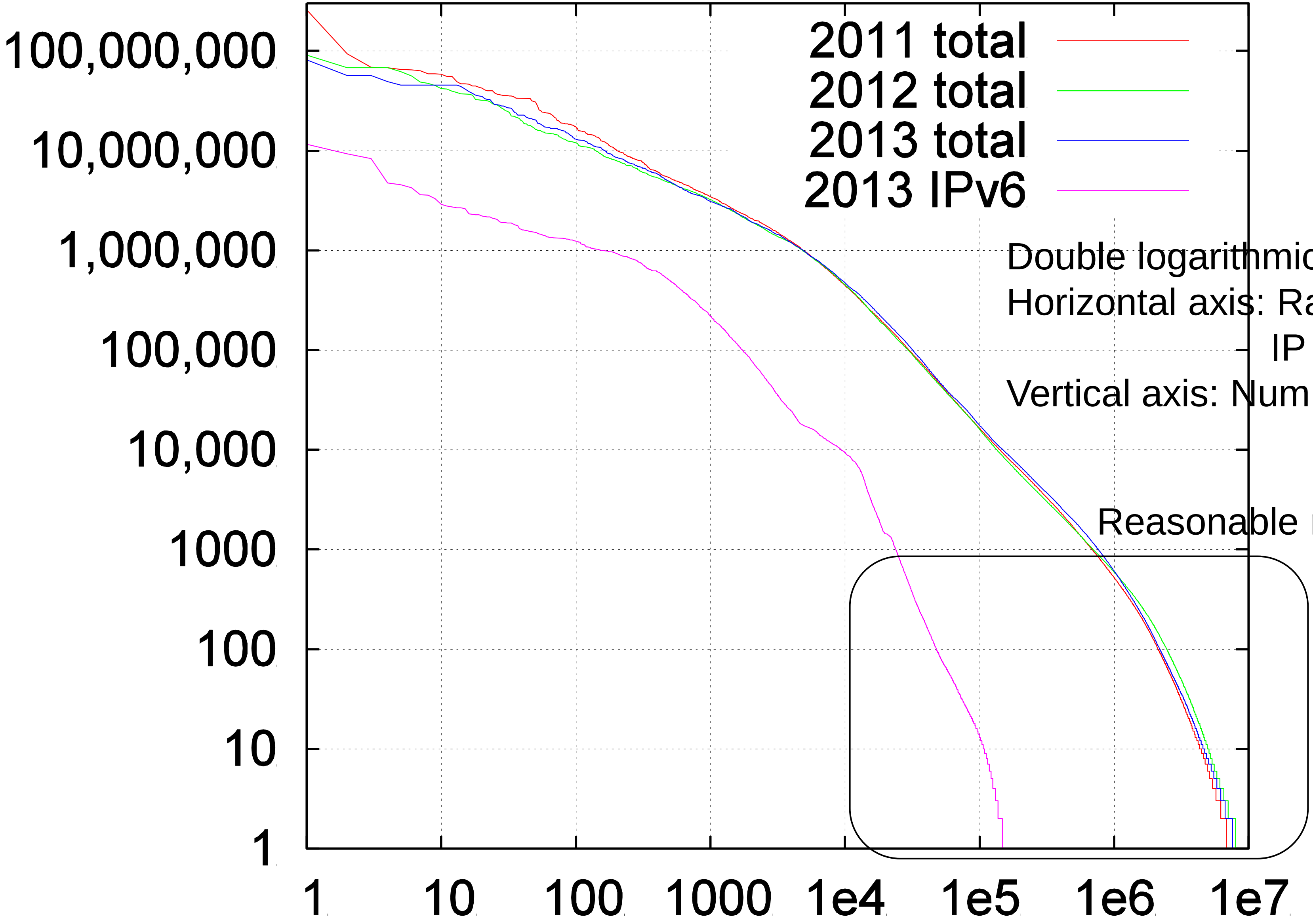
- Unknown: queries from an IP address < 10
- Static: use of High8 < 4 and use of Low8 < 4
- Limited: use of High8 < 4 or use of Low8 < 4 or OrderChange < 4 (except Static)
- Random: others (port randomization enabled?)

- This classification is under concern

Source port randomization trends



Number of queries send from each address, at root, 48 hours



Double logarithmic chart
Horizontal axis: Ranking of IP addresses
Vertical axis: Num. of queries

Reasonable resolvers?

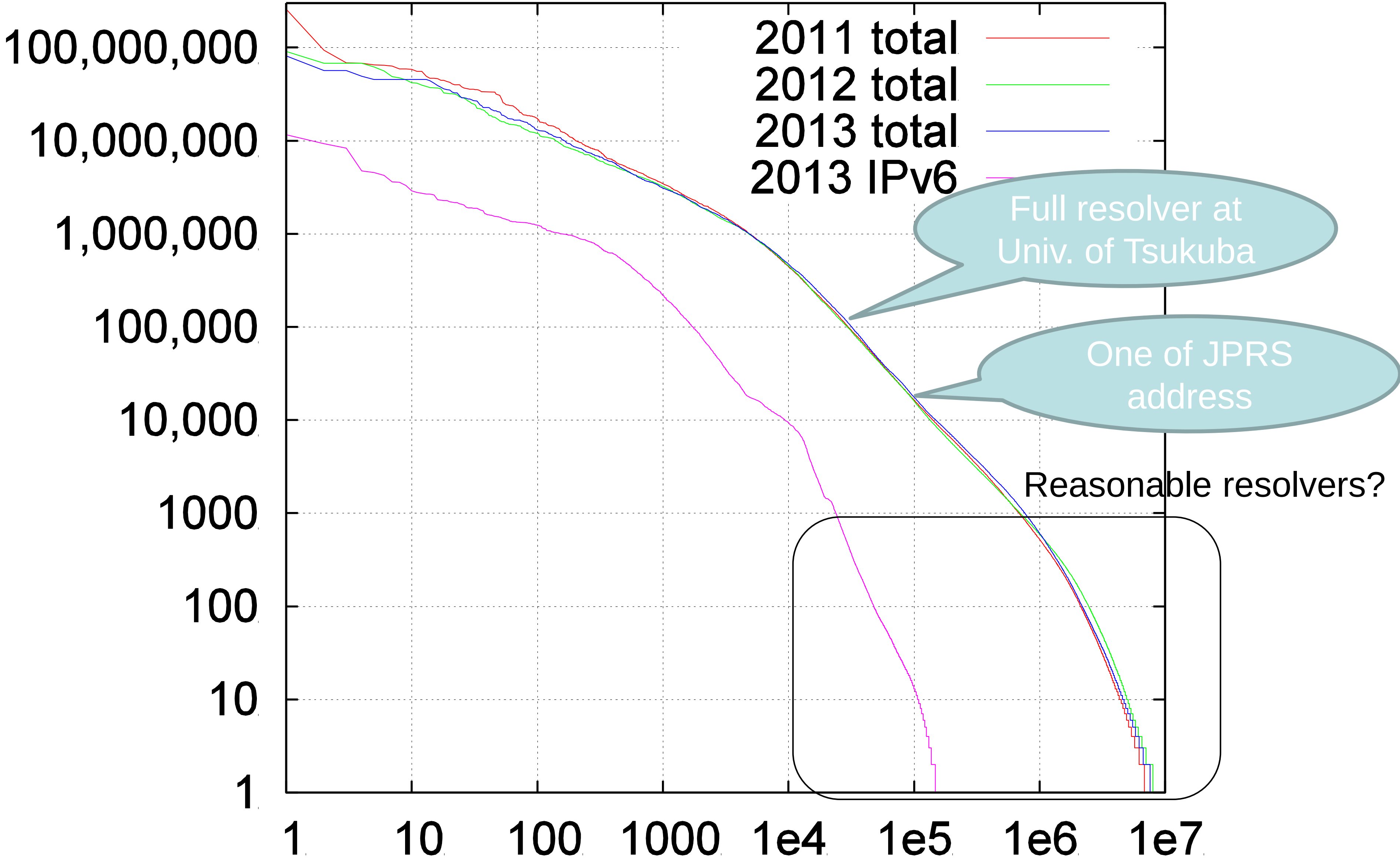
Number of queries from each address

- Without TLD typos,
- There were 318 TLDs and their NS TTLs were 172800 and DS TTLs were 86400 at May 2013
  - They should be cached within 1 or 2 days
- If resolvers work well, they should send only 2 * 318 + priming + root dnskey queries at most.
- However, there are 500,000 IP addresses which send over 1000 queries within 48 hours. Why ?
  - They send both existing names and non-existent names

Some known IP addresses

	Total queries to root	Non-existing TLD	"." queries	Existing name queries
My VPS (IPv4)	177	1	14	162
My VPS (IPv6)	182	2	12	168
My home server (IPv4)	1124	34	54	1036
One of JPRS address	21990	400	3	21587
One of full resolvers at University of Tsukuba	109215 Too many ?	12200	1298 Too Many?	95717 Too many?

Number of queries send from each address, at root, 48 hours



Full resolver at Univ. of Tsukuba

One of JPRS address

Reasonable resolvers?

Status of the full-resolver at the university

- Software: latest version of BIND 9.6 (April 2012)
- Configuration
  - Recursion only
  - Without DNSSEC validation
  - Without special configurations
- There are packet captures of the full-resolver at the same timing of DITL-2012

Analysis of full-resolver packets

- 72,355,778 packets captured (418 pps)
- 28,815,955 stub queries (166 qps)
  - 1,026,487 non-existing TLD queries
- 8429 unique query source addresses
- 7,499,961 authoritative queries
- 7,329,795 authoritative answers
  - 118,360 root answers
    - 105,781 (89.4%) RCODE 0 Too many
    - 12,579 (10.6%) RCODE 3 Reasonable
  - 687,365 TLD answers

Observations from packet capture (1)

- At out-of-bailiwick delegations, a modern full- resolver will start resolving all DNS server names A and AAAA simultaneously
  - – If the cache is empty, it will send twice as many queries as number of NS RRs to root
- TLD typos caused 12579 error responses from root
  - – Most of them were different query names
  - – Some came from small (negative) cacheable time (1 hour to 3 hours)

Observations from packet capture (2)

- The full-resolver at the university sent many DNS server name A/AAAA queries to root
  - Cacheable NS name queries are 103,024 (87%)
    - To mitigate attacks ?
    - Zone TTL is small ?
    - Why ?
- To understand this behavior more, I replayed client traffic to some full-resolvers to know that the behavior is true

Replay on some full-resolver software

- Input client traffic
  - 48 hours client query data at University of Tsukuba
  - Same timing, same qname/qtype
  - Original query source addresses are ignored
    - Sent from one IP address
- Tested full-resolvers
  - BIND 9.9.5 (with/without DNSSEC)
  - Unbound 1.4.22 (with/without DNSSEC, increased cache size, specify harden-referral)
    - large cache configuration
      - msg-cache-size: 1024m
      - rrset-cache-size: 1024m
      - infra-cache-numhosts: 500000

Results of replay

28,815,955 client queries

	To root	To root Name error	To root No error	To TLD	Auth
BIND 9.6 / Observed data	118,360	12,579	105,781	687,365	6,524,070
BIND 9.9.5	163,187	12,975	150,212	842,592	7,377,712
BIND 9.9.5 + DNSSEC	663,647	12,727	650,920	1,061,886	7,235,743
Unbound	99,923	25,914	74,309	3,916,313	16,048,069
Unbound + large cache	13,300	11,444	1,856	870,650	9,102,884
Unbound + large cache + harden referral path	20,897	11,234	9,663	2,328,026	11,152,425
Unbound + large cache + DNSSEC	12,662	11,140	1,522	1,423,789	9,112,902

Summary of replay

- It is preliminary result
  - Need more test and detailed analysis
  - Values change at every experiment
- Both BIND 9 and Unbound generated too many (around 100,000 / 48hours) root queries
  - 100,000 queries to root is real
- Queries to root increased 4 times when DNSSEC validation enabled on BIND 9
- Unbound with default configuration is not good for middle / large scale sites
  - Because Unbound with default configuration sent 74,309 positive queries to root
  - Unbound with large cache sent only 1,856 queries to root
- Using Unbound may decrease root queries. However queries to other servers may increase

Conclusion

- Port randomization is spreading gradually, however about 10% of IP addresses are still dangerous
- DITL data show that 30,000 IP addresses sent 100,000 or more queries to root DNS servers within 48 hours.
- A full-resolver at University of Tsukuba sent 118,360 queries within 48 hours to root.
- As a result of replay experiment, both BIND 9 and Unbound full-resolvers sent around 100,000 queries to root within 48hours
- BIND 9 full-resolvers may send many queries to root DNS servers
  - Unbound send smaller number of queries to root
  - Decreasing queries to root is important

Acknowledgements

- DNS-OARC as the data source of Root dataset
- Academic Computing & Communication Center offers Full-Resolver DNS servers for Campus network of University of Tsukuba